Review of Human Spaceflight Plans

Constellation Overview

June 17, 2009

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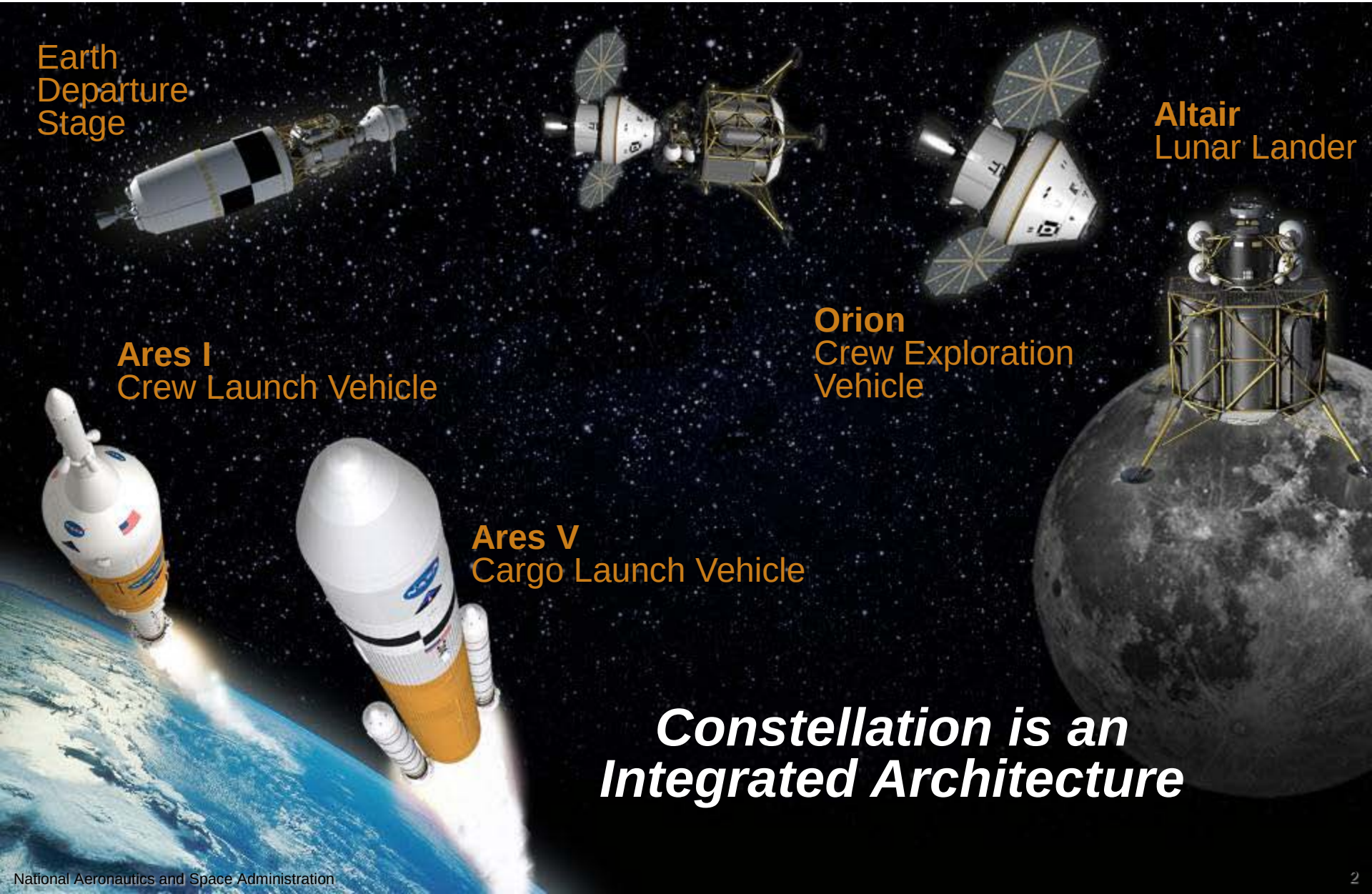
Jeff Hanley

Constellation Architecture



Key Exploration Objectives

1. Replace Space Shuttle capability, with Shuttle retirement in 2010
2. To ensure sustainability, development and operations costs must be minimized
3. Develop systems to serve as building blocks for human exploration of the solar system using the Moon as a test bed
4. Design future human spaceflight systems to be significantly safer than heritage systems
5. Provide crew transport to ISS by 2015, to the lunar surface for extended durations by 2020, and to Mars by TBD
6. Separate crew from cargo delivery to orbit
7. Maintain and grow existing national aerospace supplier base
8. Provide global lunar access to maximize science return
9. Lunar “any time return” is a safety requirement
10. Utilize ISS to support exploration goals
11. Promote international and commercial participation in exploration

Solutions Must Be Addressed Through an Integrated Architecture

Influence of Key Drivers on Architecture Selection

Exploration

NASA Developed Human Spaceflight

No → New Needs, Goals and Objectives

Yes → VSE, '05/'08 NASA Auth.

Beyond LEO?

No → New Needs, Goals and Objectives

Yes! →

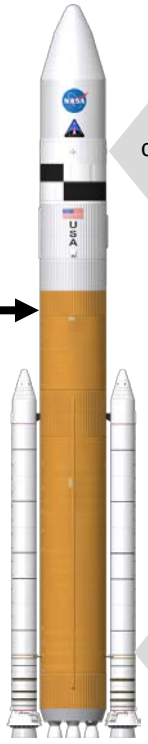
Where First?

Other → New Exploration Architecture Document, New Cx Architecture Requirements Document (CARD)

VSE, '05/'08 NASA Auth.

Moon → Lunar Surface Access (Altair)

Spacecraft (Orion)



Heavy Lift (Ares V)

Maximum commonality and cost Sharing

Crew Launch (Ares I)

Crew Transport

NASA Develop ISS Crew Transport?

No →  or  International

Yes →

Has Missions Beyond LEO

No →  Continue Shuttle or  Orbital Space Plane

Yes →

Separate Crew and Cargo

No →  Ares V  Shuttle C

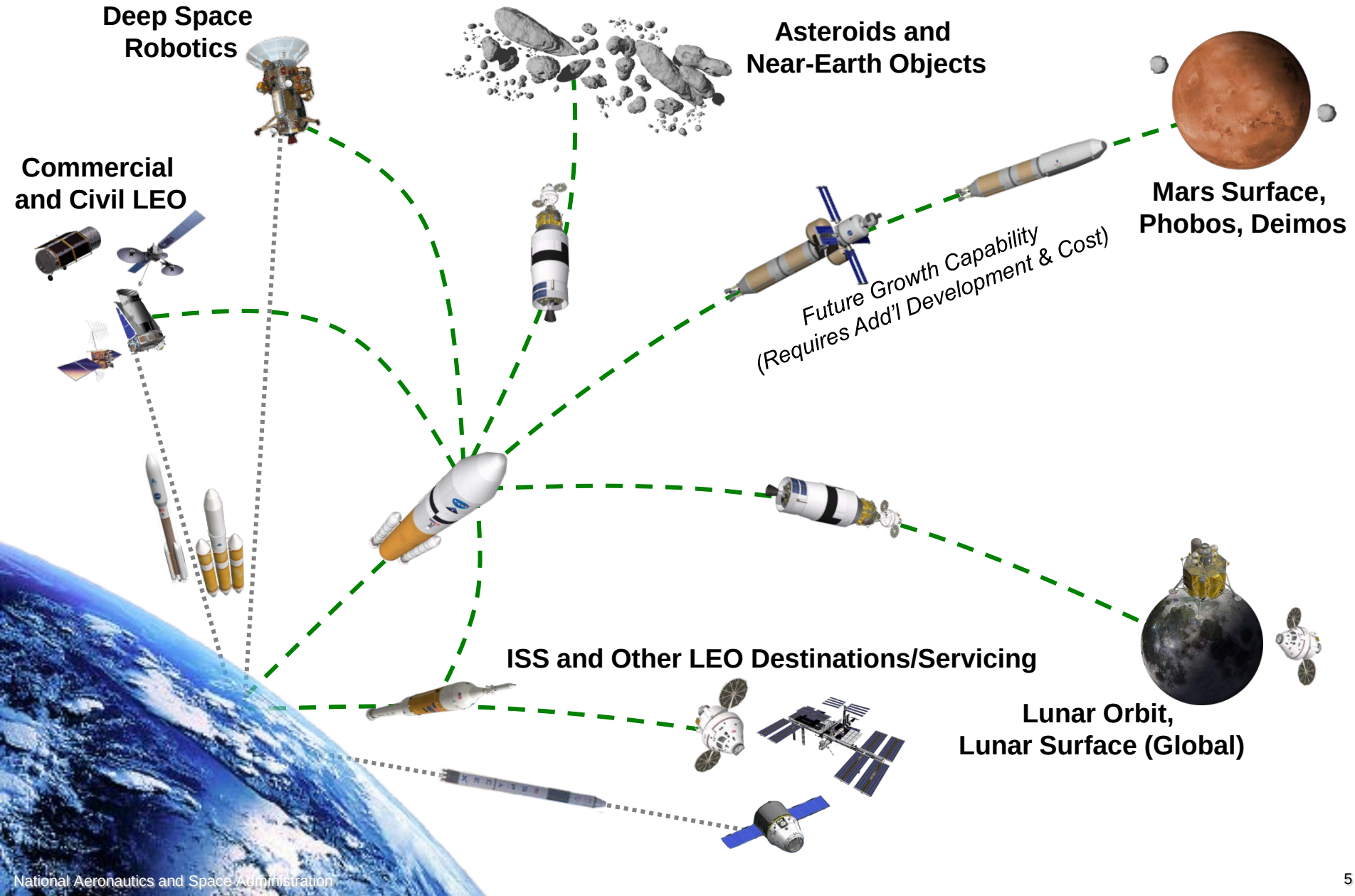
Yes →

Significant Safety Increase Over Legacy Systems

Yes → (to Crew Launch)

No →  EELV

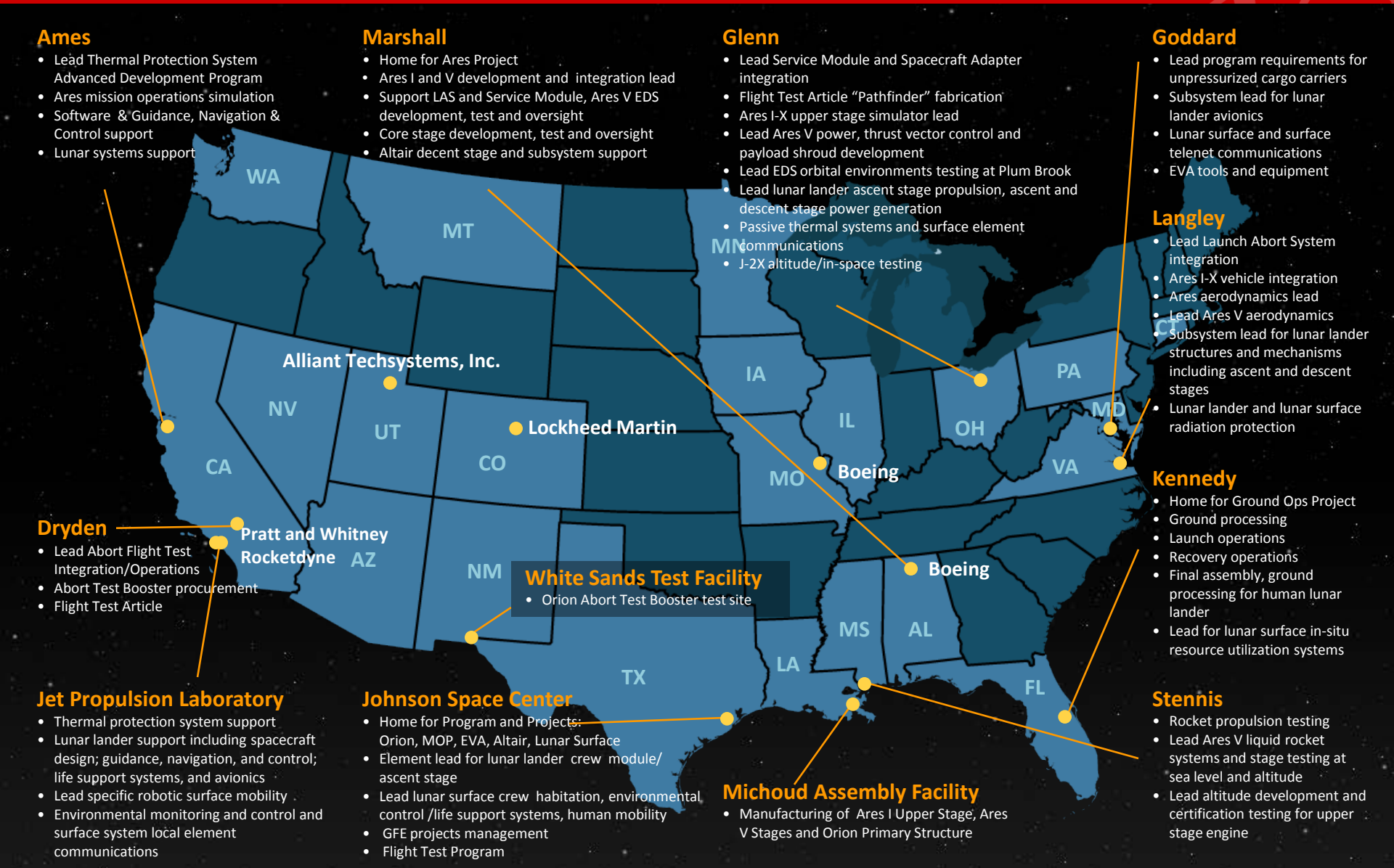
Current Development for Future Exploration Capabilities



Transition of Shuttle Capabilities

- **Constellation makes extensive use of Shuttle capabilities, but in a leaner, smaller footprint to reduce life cycle costs:**
  - JSC: Crew systems and mission operations
  - KSC: LC39, VAB, O&C, SSPF
  - MSFC: Large scale launch vehicle development and test
  - SSC: Large scale liquid propulsion test
  - MAF: Large scale cryogenic stage production
  - ATK: Large solid rocket motor development, production and test
  - PWR: Large liquid engine development and production
- **Significant synergy in capabilities of the human spaceflight workforce between Shuttle, ISS and Constellation**
- **Challenge is in converting a large, fixed base LEO-capable workforce to a beyond-LEO architecture in a cost effective manner**
- **The U.S. has a unique, once-in-a-generation opportunity to capitalize on Apollo and Shuttle investments**

Constellation Economic Impact: Civil Servant (2,950 FTE)



Ames
- Lead Thermal Protection System Advanced Development Program
- Ares mission operations simulation
- Software & Guidance, Navigation & Control support
- Lunar systems support

Marshall
- Home for Ares Project
- Ares I and V development and integration lead
- Support LAS and Service Module, Ares V EDS development, test and oversight
- Core stage development, test and oversight
- Altair decent stage and subsystem support

Glenn
- Lead Service Module and Spacecraft Adapter integration
- Flight Test Article "Pathfinder" fabrication
- Ares I-X upper stage simulator lead
- Lead Ares V power, thrust vector control and payload shroud development
- Lead EDS orbital environments testing at Plum Brook
- Lead lunar lander ascent stage propulsion, ascent and descent stage power generation
- Passive thermal systems and surface element communications
- J-2X altitude/in-space testing

Goddard
- Lead program requirements for unpressurized cargo carriers
- Subsystem lead for lunar lander avionics
- Lunar surface and surface telenet communications
- EVA tools and equipment

Langley
- Lead Launch Abort System integration
- Ares I-X vehicle integration
- Ares aerodynamics lead
- Lead Ares V aerodynamics
- Subsystem lead for lunar lander structures and mechanisms including ascent and descent stages
- Lunar lander and lunar surface radiation protection

Kennedy
- Home for Ground Ops Project
- Ground processing
- Launch operations
- Recovery operations
- Final assembly, ground processing for human lunar lander
- Lead for lunar surface in-situ resource utilization systems

Dryden
- Lead Abort Flight Test Integration/Operations
- Abort Test Booster procurement
- Flight Test Article

White Sands Test Facility
- Orion Abort Test Booster test site

Jet Propulsion Laboratory
- Thermal protection system support
- Lunar lander support including spacecraft design; guidance, navigation, and control; life support systems, and avionics
- Lead specific robotic surface mobility
- Environmental monitoring and control and surface system local element communications

Johnson Space Center
- Home for Program and Projects: Orion, MOP, EVA, Altair, Lunar Surface
- Element lead for lunar lander crew module/ ascent stage
- Lead lunar surface crew habitation, environmental control /life support systems, human mobility
- GFE projects management
- Flight Test Program

Michoud Assembly Facility
- Manufacturing of Ares I Upper Stage, Ares V Stages and Orion Primary Structure

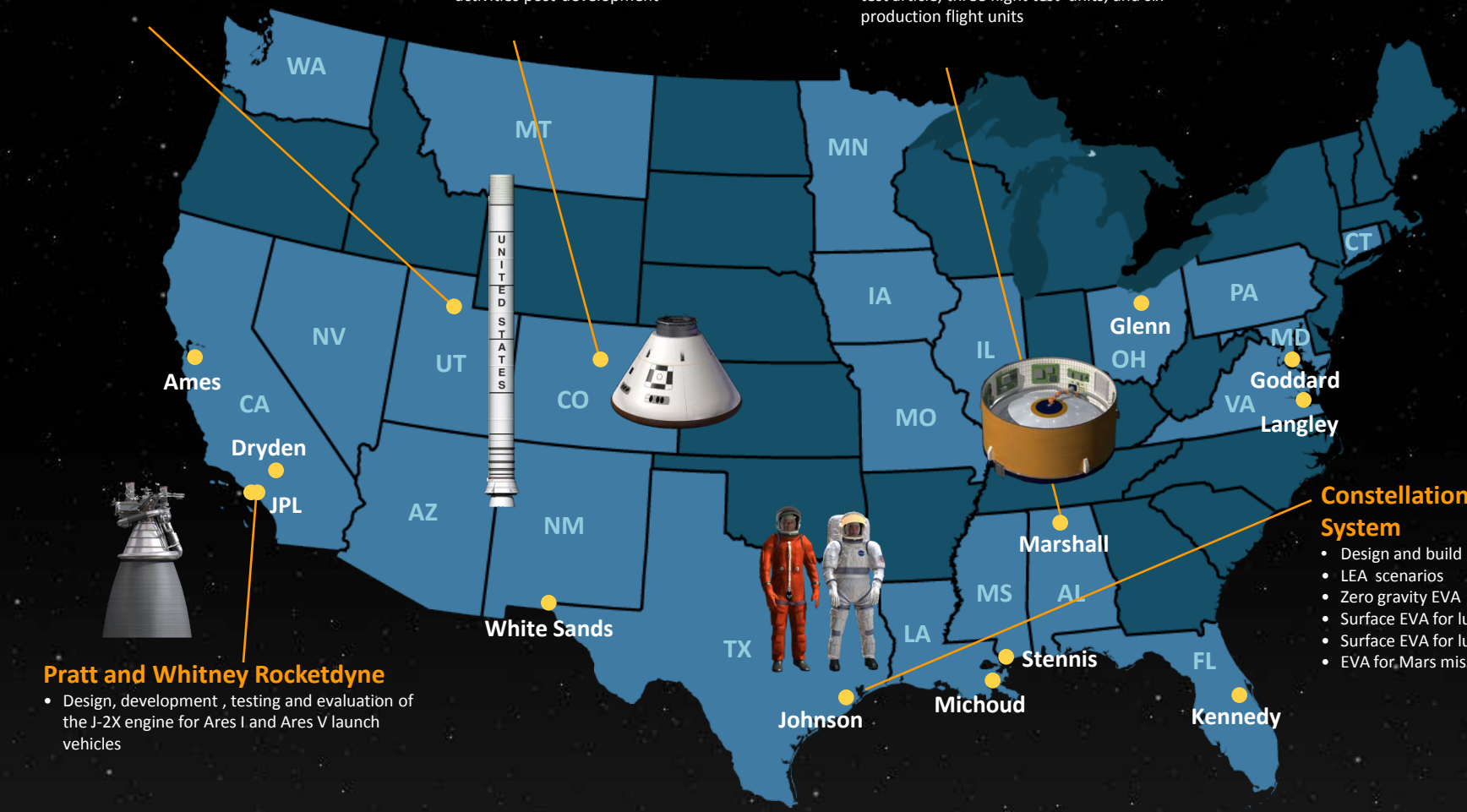
Stennis
- Rocket propulsion testing
- Lead Ares V liquid rocket systems and stage testing at sea level and altitude
- Lead altitude development and certification testing for upper stage engine

Constellation Economic Impact: Contractor (7,530 WYE)

Alliant Techsystems, Inc.
- Build five ground static test motors, two ground vibration test articles, and four flight test stages.

Lockheed Martin
- Engineer, assemble, and integrate the Orion vehicle
- Production and sustaining engineering activities post-development

Boeing
- Produce, deliver and install avionics systems for Ares I rocket
- Provide one instrument unit avionics ground test article, three flight test units, and six production flight units

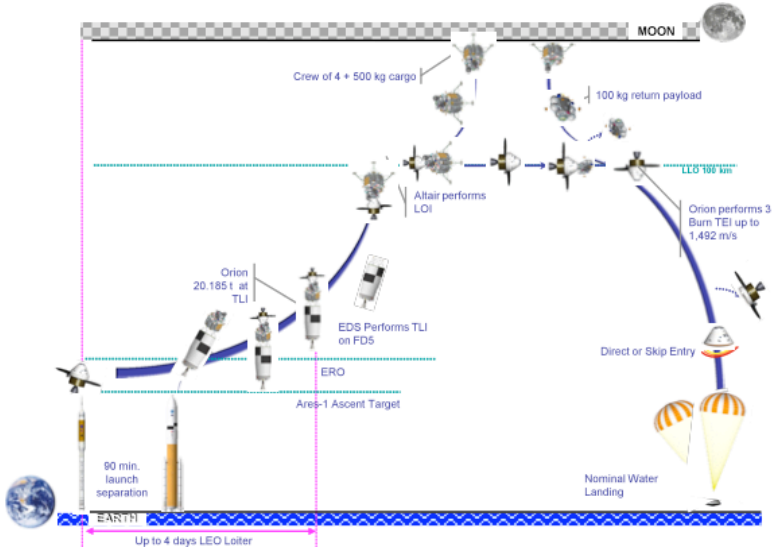


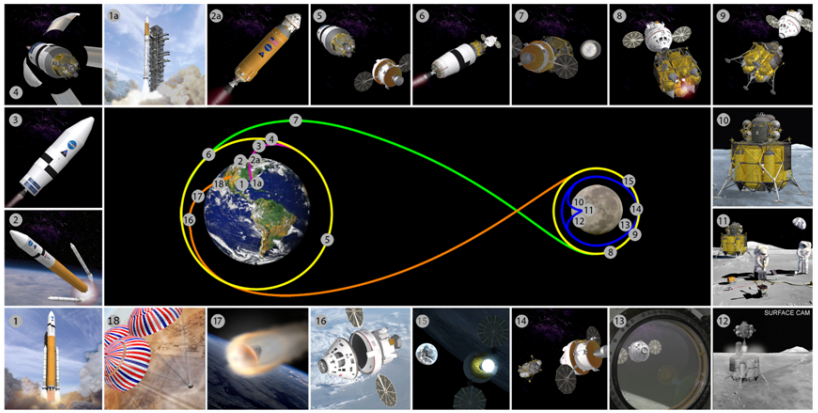
Pratt and Whitney Rocketdyne
- Design, development , testing and evaluation of the J-2X engine for Ares I and Ares V launch vehicles

Constellation Space Suit System
- Design and build space suits for
- LEA scenarios
- Zero gravity EVA
- Surface EVA for lunar sorties
- Surface EVA for lunar outpost
- EVA for Mars missions

Overview of Lunar Capability

- **Constellation Transportation Architecture Enables Independent Delivery of Crew and Large Cargo to the Surface of the Moon:**
  - 4 crew members
  - 7 days (living out of lander in sortie mode)
  - 210 days (crew at outpost with lander waiting in standby)
  - Global surface access
  - Anytime return to Earth
  - 14 metric ton cargo to surface on a single launch
- **Lunar Surface Systems Currently Under Study, Including Contributions from International Partners**

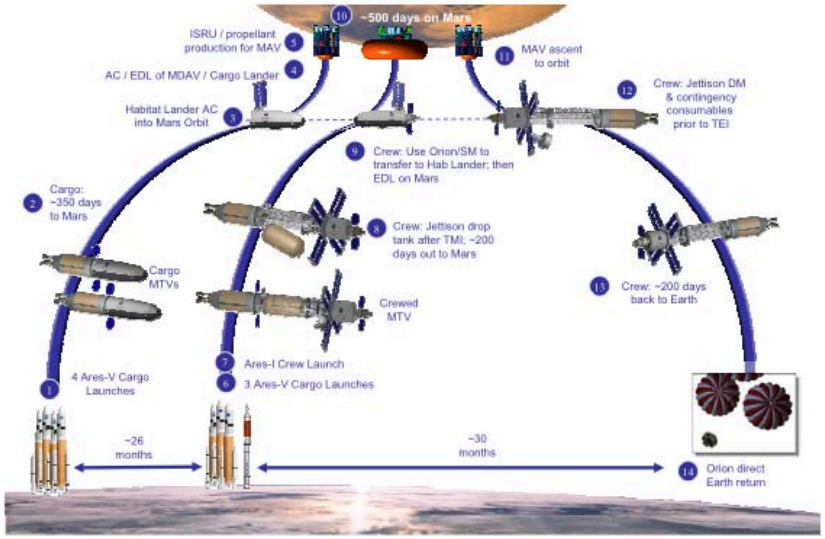


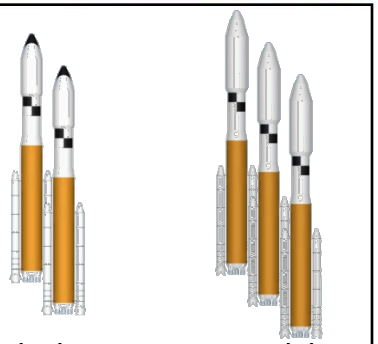


1. Ares V liftoff.
2. Solid Rocket Booster (SRB) separation.
3. Earth Departure Stage (EDS) fires for Earth Orbit Insertion (EOI).
4. Payload shroud separates to expose Altair Lunar Lander.

1a. Ares I liftoff.
2a. Upper Stage fires for EOI.
5. Orion docks with Altair/EDS.
6. EDS fires for Trans-Lunar Injection (TLI).
7. Orion and Altair undock from EDS.
8. Altair fires for Lunar Orbit Insertion (LOI).
9. Altair separates from Orion.
10. Altair lands on lunar surface.
11. Conducting activities on the lunar surface.
12. Altair ascent stage liftoff viewed from surface camera.
13. Altair ascent stage prepares to dock with Orion.
14. Altair ascent stage and Orion separate.
15. Service Module (SM) fires for Trans Earth Injection (TEI).
16. Orion separates from SM.
17. Orion re-enters Earth atmosphere.
18. Chutes open for recovery.

Overview of Mars Extensibility

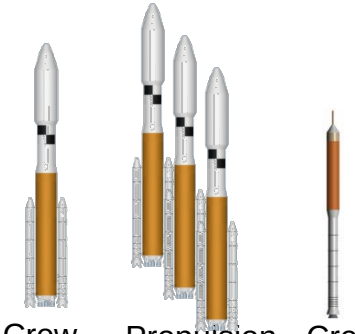




Mission Cargo (2) | Propulsion Systems (3)

Cargo Mission
- Surface Habitat
- Cargo Lander
- Outbound Propulsion

Previous Opportunity
5 Ares V Launches

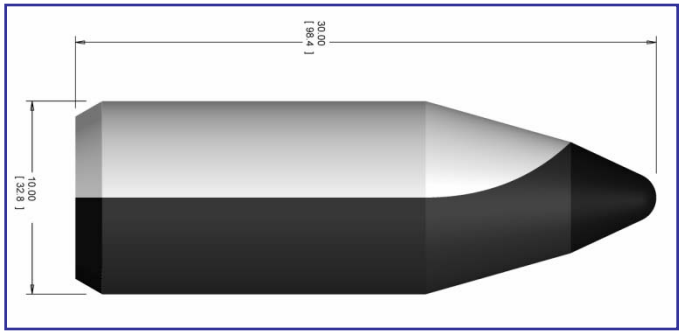


Crew Hab (1) | Propulsion Systems (3) | Crew

Crew Mission
- Transfer Habitat
- Roundtrip Propulsion
- Orion

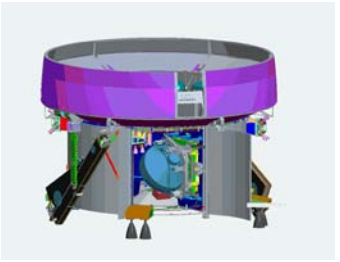
Current Opportunity
4 Ares V Launches

- **Current Human Mars Mission Highlights:**
  - Long stay (conjunction)
  - Pre-deployed assets
  - Nuclear thermal in-space propulsion
  - 9 Ares V launches
  - Preliminary assessments indicate launch vehicle shroud can be used for both ascent to LEO as well as entry, descent, & landing aeroshell structural element



Architecture Flexibility Enables New Science and DoD Applications

- **Orion Will Fully Utilize Vehicle System Capabilities to Accommodate a Variety of Prospective Payloads**
  - Heliophysics, Environmental Monitoring, Atmospheric and Oceanic Studies, Laser Communications Satellites and Dust Studies
- **"It is very clear from the outset that the availability of the Ares V changes the paradigm of what can be done in planetary science."** – *Workshop on Ares V Solar System Science*
- **"Exciting new science may be enabled by the increased capability of Ares V. The larger launch mass, large volume, and increased C3 capability are only now being recognized by the science community."**– *National Academy of Science's "Science Opportunities by NASA's Constellation Program*
- **Large Optics Are Needed By Many National Security Applications**
- **An 8+ M Surveillance System at GEO Could Provide 24/7 Coverage of Military or Politically Significant Areas**
- **Optic Size and Mass Are Limited By Current Launch Vehicles**



Orion Unpressurized Cargo

Ares V will have the largest payload and volume capability of any existing launch system

Status on Key Constellation Issues

- **Integrated Performance Across the Mission Phases**
  - Element level control masses are established to ensure integrated performance
  - ISS mission total margin: Ares I: 22% / Orion: 23% / Cx: 5%
  - Lunar mission total margin: Ares I: 18% / Orion: 10% / Cx: 4%
  - Orion Crew Module mass limit set by recovery system and water landing constraints, not by Ares lift mass

- **Tower Clearance/Launch Drift**
  - All launch vehicles experience drift due to winds at the pad
  - Ares being designed for a 34 knot wind requirement
  - No contact with pad assured by either: 1) constraining Southerly winds to 15-20 knots and/or 2) steering at liftoff (Saturn V). Focus now is on best combination to minimize plume damage

- **Induced Environments : Thrust Oscillation and Vibroacoustics**
  - All launch vehicles experience vibration
  - Thrust oscillation occurs because stack and motor resonance frequencies align late in 1st stage flight
  - Pursuing baseline solution plus alternatives that will reduce loads to crew performance requirements with high (3 sigma) confidence
  - All subsystems being designed to accommodate / mitigate liftoff and flight vibroacoustics

Status on Key Constellation Issues (cont'd)

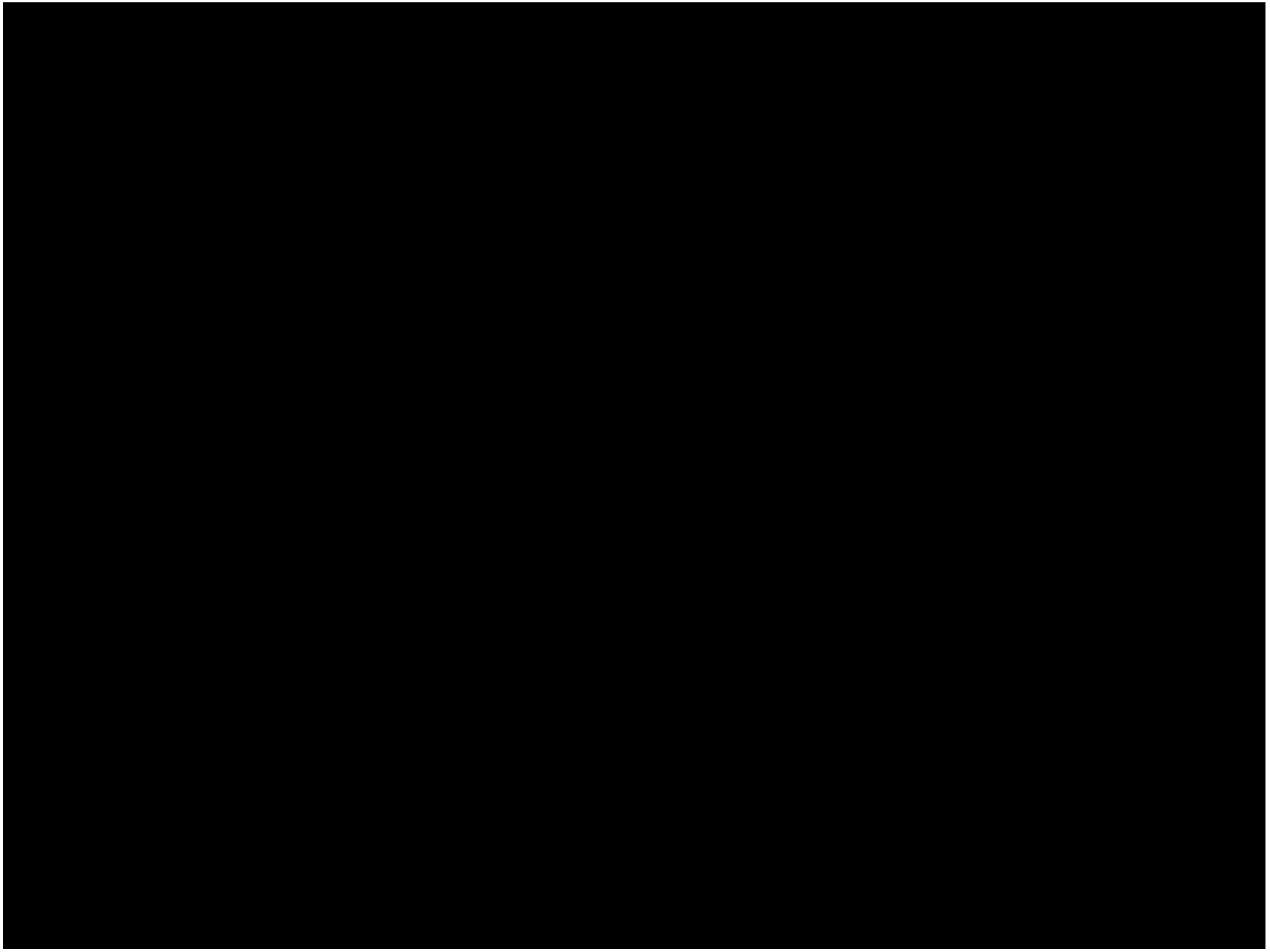
- **Ares/Orion Loss of Mission/Loss of Crew**
  - Ares and Orion are being designed from the outset to maximize crew safety
  - Goal is to be 10x safer than Shuttle (LOC of 1:160-270)
  - Current ascent estimate is 1 in 2,850 for a loss of crew event
  - To date, over 60 vehicle design changes on Orion have been made to improve LOC/LOM during 5 design/analysis cycles.

- **Post Landing Crew Survival**
  - Orion design supports several contingencies: including land landing and a minimum of 24 hours of crew water survival time

- **Budget requirement through 2015**
  - Current requirement for IOC capability is $35B at 65% confidence
  - Original plan was to spend an additional $9B on lunar system developments (Ares V, Altair, etc)

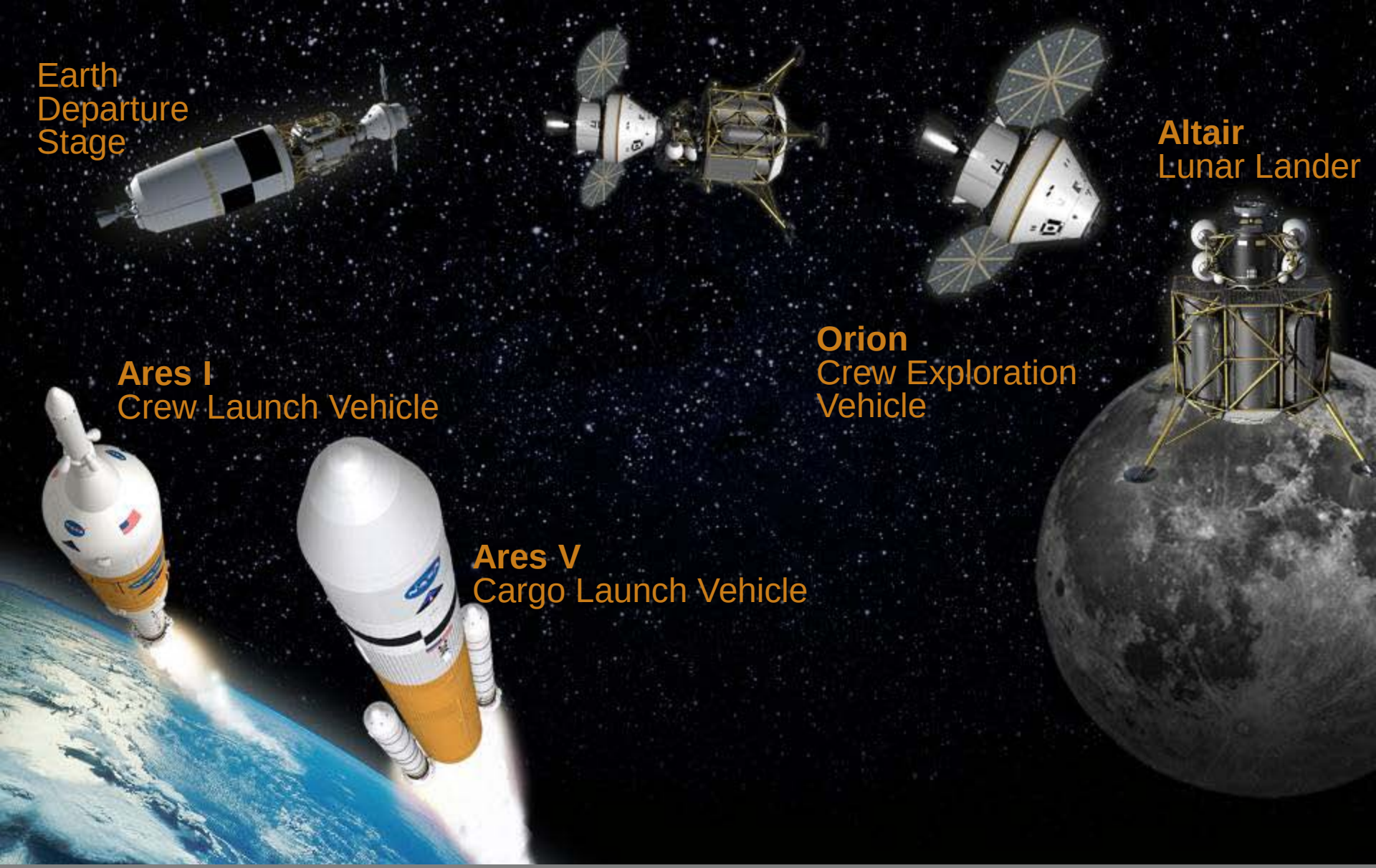
- **Schedule for ISS initial operating capability**
  - External commitment stable at March, 2015
  - Methods to improve schedule confidence were recommended in early FY09 study
  - Program-wide content review in progress
  - 6 vs 4 crew on Orion was driven by these activities

3 Years of Progress



Summary

- **NASA's near term plan is to maintain March 2015 goal for the first crewed Orion/Ares flight to the International Space Station**
  - Maximizing existing resources to reduce risk; funding increases in FY09 and FY10 improve ability to meet schedule
- **Technical progress to date is substantial; Constellation preparing for system level Preliminary Design Review (PDR)**
  - Ares I PDR complete; preparing for Orion PDR as testing continues on critical components and subsystems
  - Abort motor static test for the launch abort system (LAS) ,(11/08)
  - LAS attitude control motor high thrust test firings #6 and #8 (1/09 and 3/09)
  - Orion post landing and recovery testing (1/09-4/09)
  - Ares drogue parachute drop test #2 (2/09)
  - Completed KSC operations and checkout facility renovation and modification for Orion spacecraft assembly, modification, integration and test (1/09)
  - Completed launch pad lightning protection towers (2/09)
  - Mobile launcher platform-1 handover for Ares I-X test flight modifications (3/09)
- **NASA has a point of departure exploration architecture which enables many missions / destinations**
- **We continue to conduct trades to improve life cycle cost, safety, reliability and technical performance**



For the Latest On the Constellation System and Accomplishments: www.nasa.gov/Constellation

Technical Progress
Hardware Fabrication and Testing – Ares I

J2X Workhorse Gas Generator Test

Deceleration Subsystem (DSS) Drogue Parachute Drop Test (DDT–1)

Friction Stir weld being performed on the new Vertical Weld Tool at MSFC, AL

Common Bulkhead Dome Delivery

Shell Buckling Test 2/5/09, MSFC

A3 Test Stand Subscale Diffuser Test

Technical Progress
Hardware Fabrication and Testing – Ares I

Engineers prepare for Ares I parachute Tests

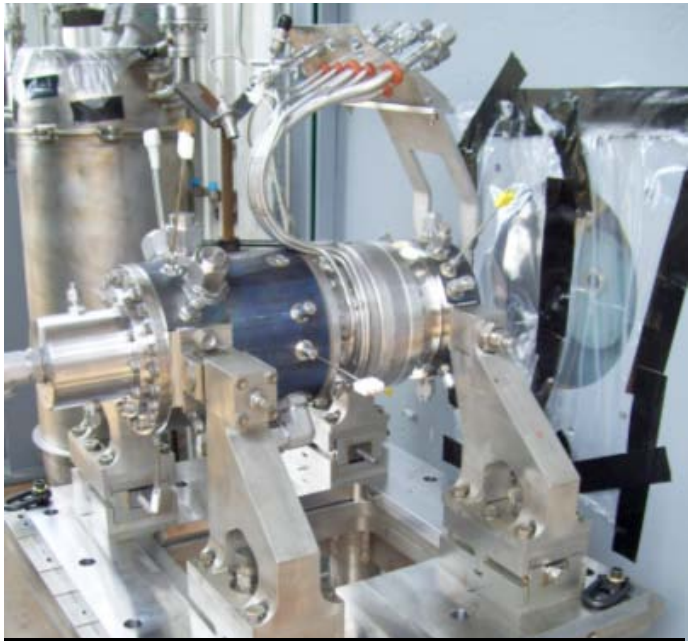
Ares I main cluster parachute test

Development Motor X-ray setup

Development Motor Igniter Test

Technical Progress
Hardware Fabrication and Testing – Ares I

Workhorse Gas Generator Turbine Simulator Test

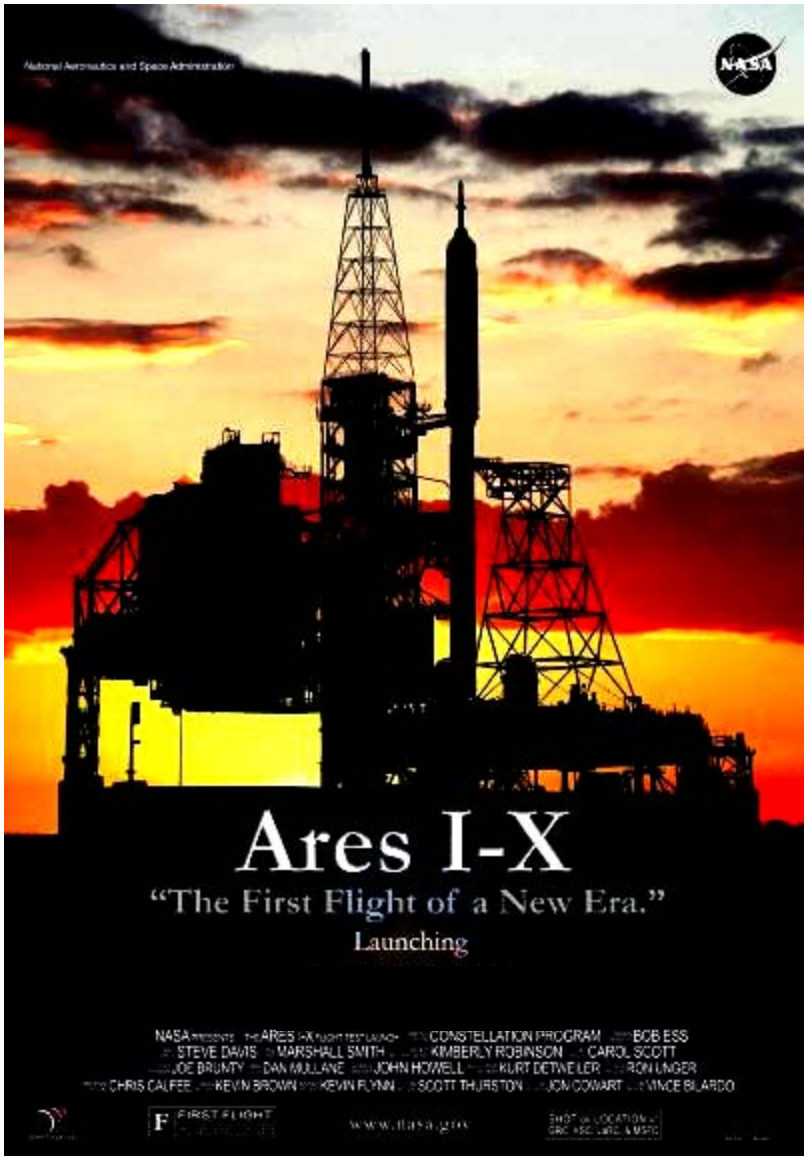


Seal Tester at MSFC's Test Stand 500

Upper Stage robotic weld tool

Progress Towards Launch

- **Ares I-X is an uncrewed, sub-orbital development flight test**
- **Ares I-X is the first flight of the Constellation Program**
- **Ares I-X provides the opportunity to test ground facilities and operations at Kennedy Space Center**
- **Ares I-X provides the opportunity to test flight operations**
  - 1st stage recovery
  - Guidance and Navigation
  - Aero acoustics
- **Ares I-X is on track for a 2009 launch date**

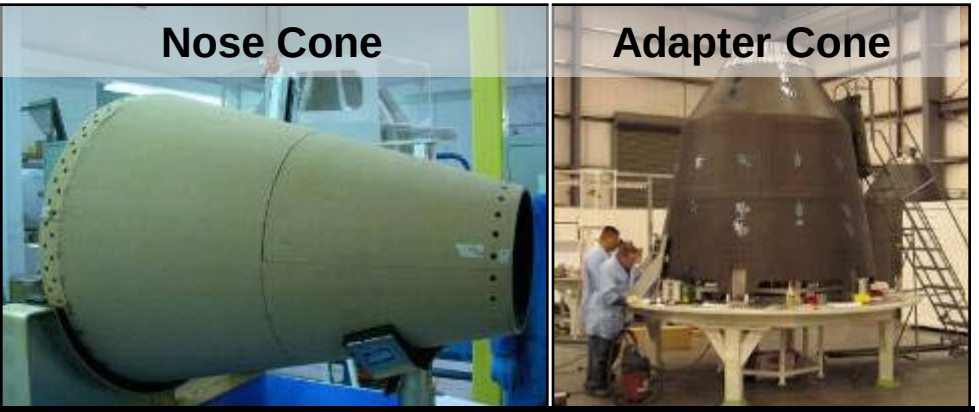


Technical Progress
Ares I-X

Technical Progress
Hardware Fabrication and Testing – Orion

The boilerplate Orion crew module used for the Orion Launch Abort System Pad Abort-1 flight

I-X Crew Module and Launch Abort System Arrive at KSC



PA-1 Launch Abort Systems Composite Structural Elements

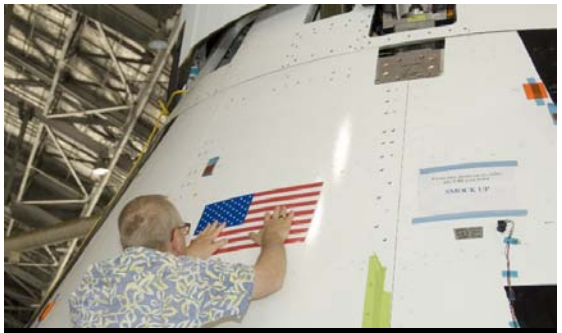
Launch Abort System (LAS) PA-1 Modal Test 12/11/08

Technical Progress
Hardware Fabrication and Testing – Orion

Orion's jettison motor is prepared for shipment to White Sands Test Facility

Pad Abort-1 Flight Crew Module

O&C Building Ribbon Cutting



Orion test module that will be flown in the Launch Abort System flight tests

Technical Progress
Hardware Fabrication and Testing – Orion

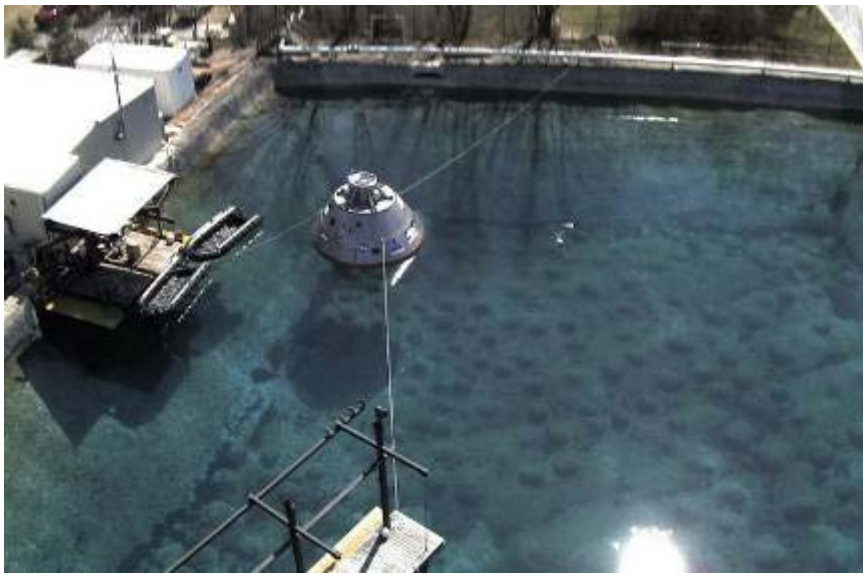
Downselect of Avcoat & Thermal Protection System Transition

Arc Jet Testing

Ascent Abort Gantry Construction

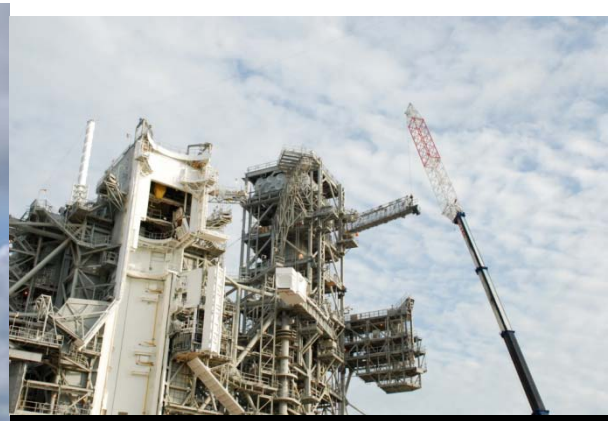
Operations and Checkout Facility

Technical Progress: Orion PORT Test



Technical Progress
Construction of Facilities

J2X A3 Altitude Test Stand Construction



Ares I-X USAA at Pad 39B FSS

Launch Complex 39B Lightning Protection System Construction

Orion Manufacturing Facilities at KSC

Hangar AF Mods & Upgrades (Phase I) ~ 90% complete

FSAM installed onto RSS

Technical Progress – Ground Operations

Launch Control Center Firing Room 1

Mobile Launch Platform construction

Technical Progress

Hardware Fabrication and Testing – EVA Systems

Suit Don/Doff Volume Assessment

Handrail Translation Demonstration

Altair Hatches Ingress/Egress Test

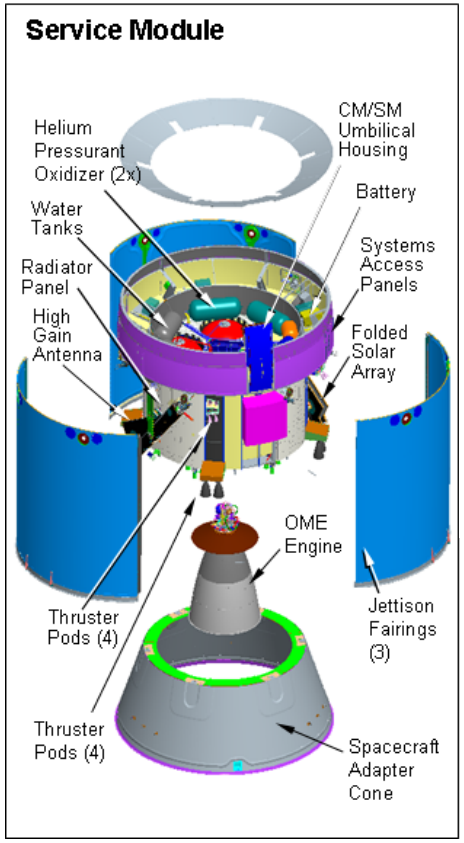
Orion Hatch Ingress/Egress

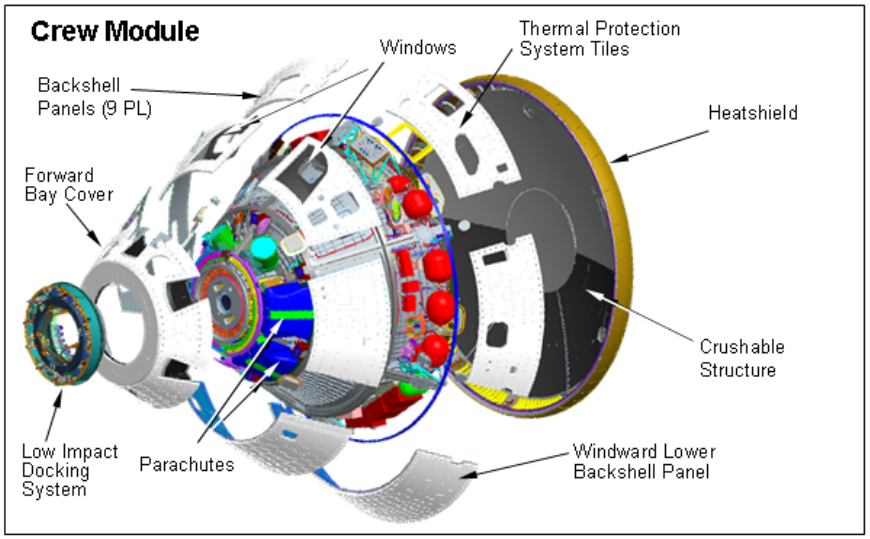
Backup Information

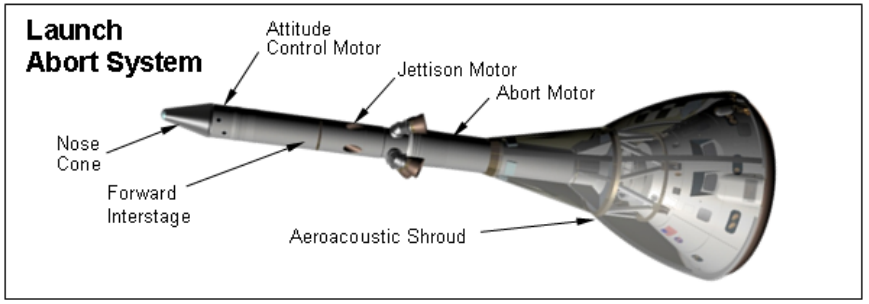
Orion Elements

Over $6.3B in Prime Contract Value

- ***Prime Integration Contractor Team***
  - Lockheed Martin-led consortium with:
    - Honeywell
    - Hamilton Sundstrand
    - Aerojet
    - Orbital Sciences
    - United Space Alliance
- ***Contract Value***
  - $6.3B through 2014 for two spacecraft



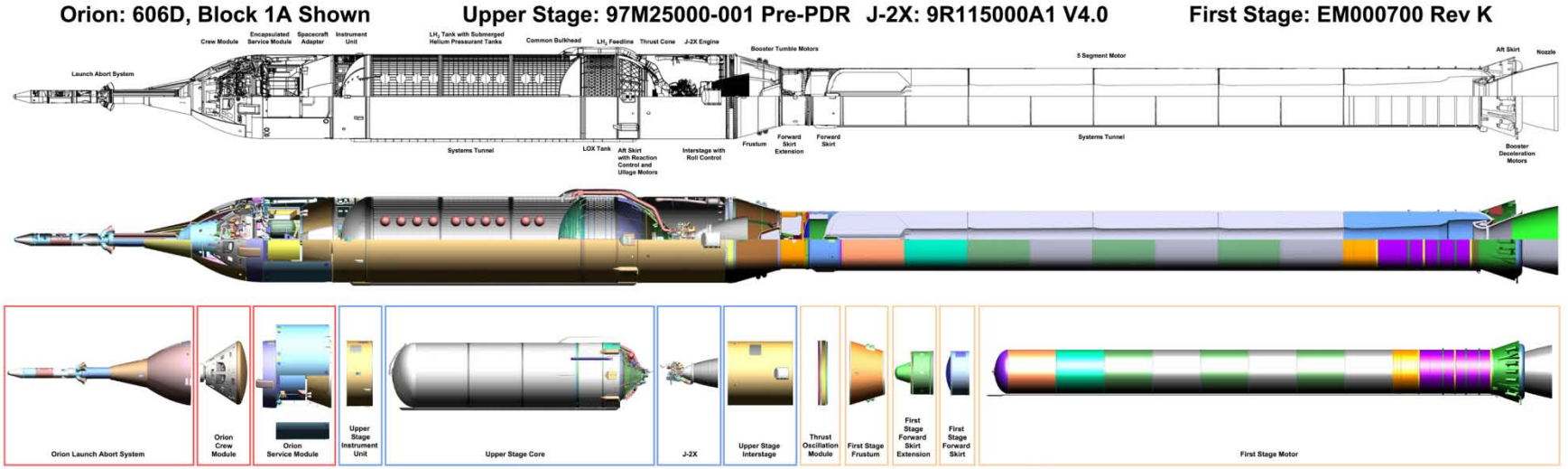




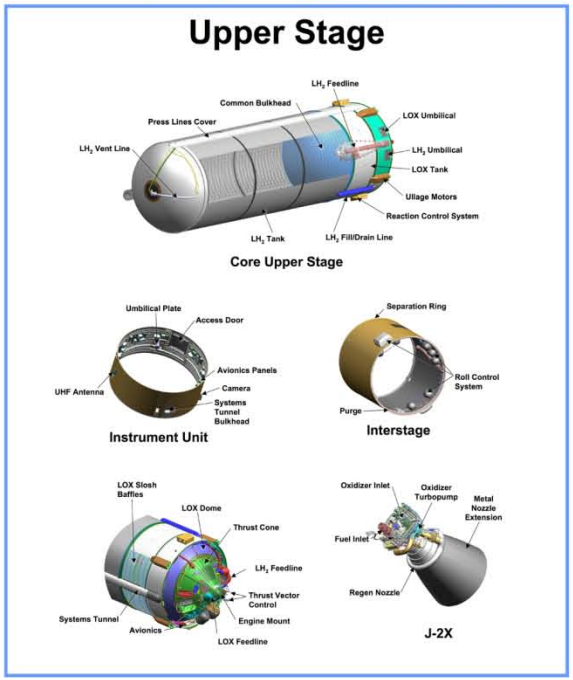
- ***Procurement Approach***
  - Single contract award through full and open competition for the design, development, test, & evaluation of the Orion crew exploration vehicle. Follow-on schedules for production and sustaining and operations support.
  - Contract type: CPAF

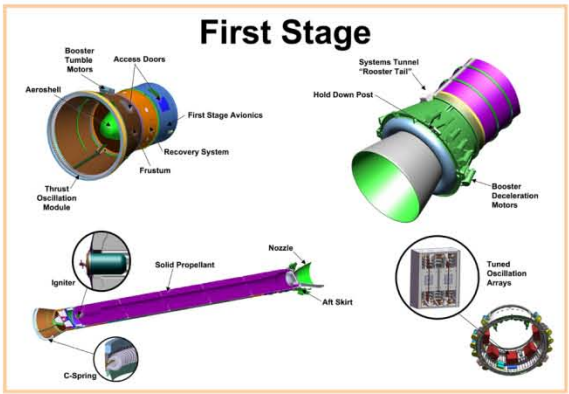
Ares I Elements (A106)

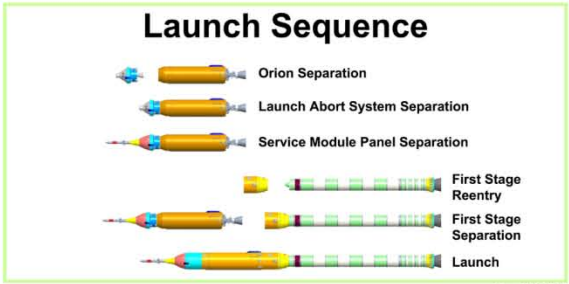
Over $5.18B in Prime Contract Value



- ***Instrument Unit***
  - NASA design
  - Boeing production
  - $0.8B contract value
- ***Upper Stage***
  - NASA design
  - Boeing production
  - $1.14B contract value
- **Upper Stage Engine (J-2X)**
  - Saturn derived
  - Pratt & Whitney/Rocketdyne
  - $1.28B contract value
- **First Stage**
  - Shuttle derived
  - ATK Space Systems
  - $1.96B contract value





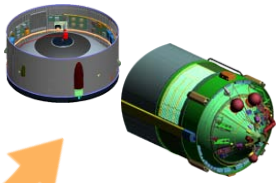


April 2009

Ares I and Ares V Commonality

- Builds Up Flight Reliability on the Smaller Vehicle, Earlier
- Lowers Life Cycle Cost

Upper Stage-Derived Vehicle Systems



J-2X Upper Stage Engine

Elements from Shuttle

Ares I

First Stage (5-Segment RSRB)

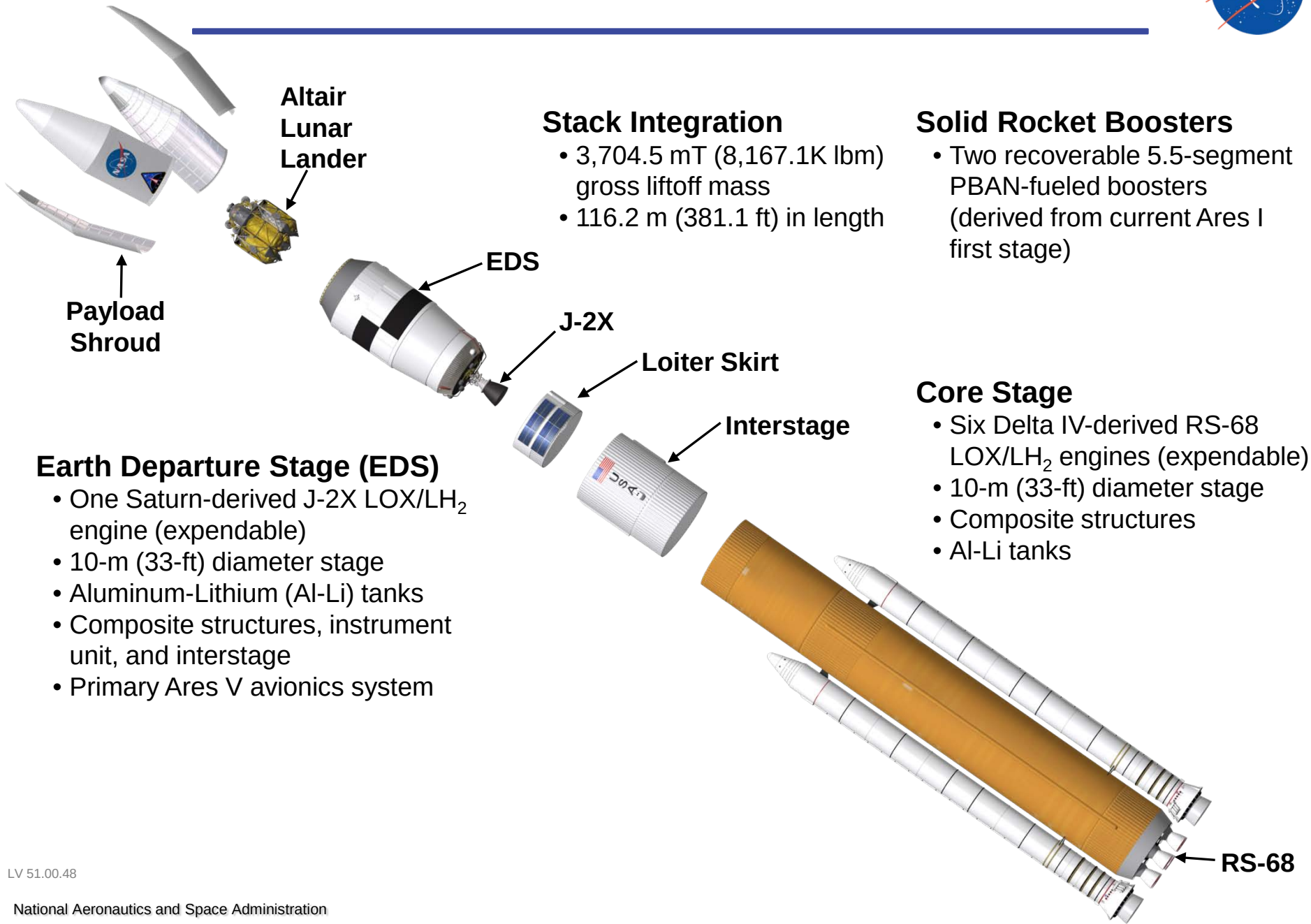
Elements from Ares I

Range: full stage to case/nozzle/booster systems

Ares V

USAF RS-68B From Delta IV RS-68

Ares V Elements



Stack Integration

- 3,704.5 mT (8,167.1K lbm) gross liftoff mass
- 116.2 m (381.1 ft) in length

Solid Rocket Boosters

- Two recoverable 5.5-segment PBAN-fueled boosters (derived from current Ares I first stage)

Earth Departure Stage (EDS)

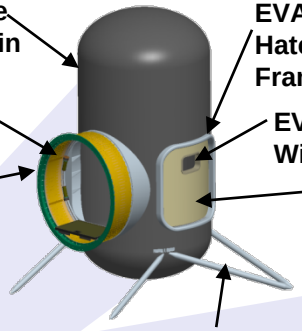
- One Saturn-derived J-2X LOX/LH_2 engine (expendable)
- 10-m (33-ft) diameter stage
- Aluminum-Lithium (Al-Li) tanks
- Composite structures, instrument unit, and interstage
- Primary Ares V avionics system

Core Stage

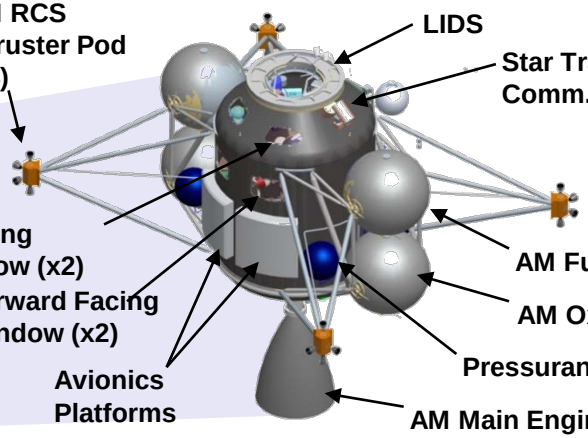
- Six Delta IV-derived RS-68 LOX/LH_2 engines (expendable)
- 10-m (33-ft) diameter stage
- Composite structures
- Al-Li tanks

Altair Elements

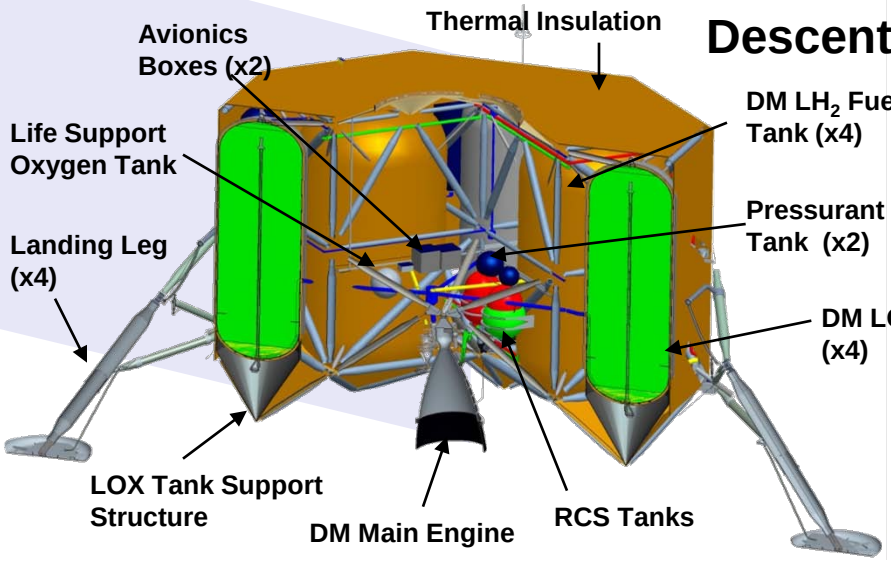
Airlock



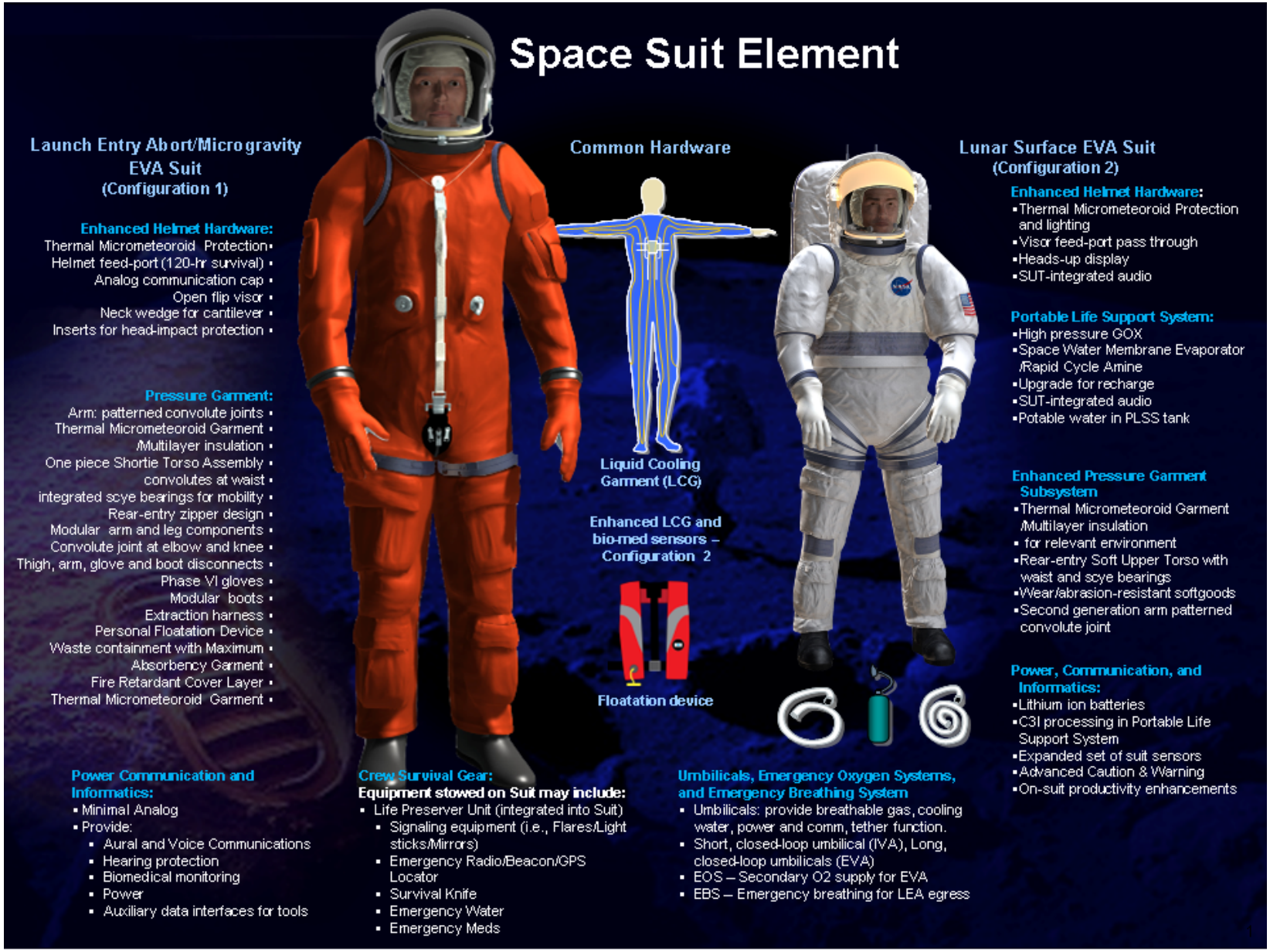
Ascent Stage



Descent Stage

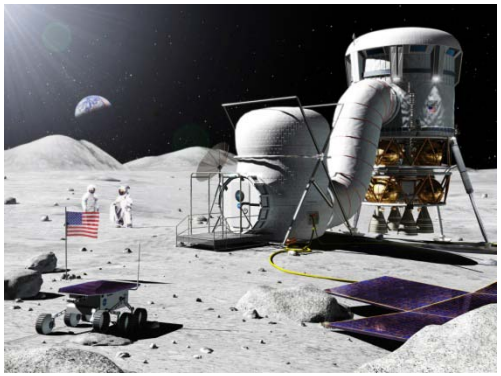


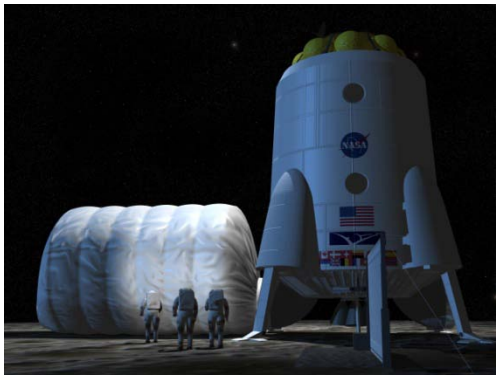
EVA Key Capabilities

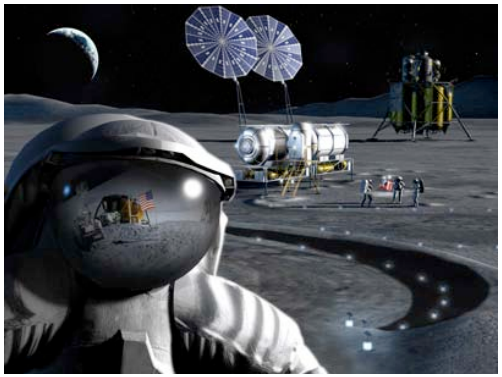


Lunar Surface Systems
Key Capabilities

- **Early Lunar Surface System Studies Explored Lunar Outpost Concepts Which Drove Out Key Issues and Informed Altair/Ares V Requirements Development**
  - Lunar Architecture Team (LAT)-1 in 2006
  - LAT-2 in 2007
  - LCCR in 2008
- **Key Capabilities**
  - Sortie, Extended Stay, and Outpost capability
  - Pervasive Mobility; ability to explore an extended range (25–100 km) around landing sites
  - Solar power with sufficient energy storage to keep assets alive between human visits
  - Habitation
  - Emphasis on understanding the lunar environment and its applicability to human exploration objectives
    - Developing & testing science protocols
    - Testing planetary protection approaches
    - Improving reliability and functionality of EVA & life support systems
    - Testing systematic approaches for resolving complex problems such as dust mitigation and radiation protection
- **NASA's Point of Departure Surface Architecture Will Be Informed by NASA's Lunar Exploration Objectives As Well As International Partner Interests and Budget**







Pervasive Mobility Scenario